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Earliest record of *Sinicuon* in Zanda Basin, southern Tibet and implications for hypercarnivores in cold environments

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ABSTRACT

The "out of Tibet" hypothesis envisions late Cenozoic Tibetan mammals acquiring adaptations to cold environments and being ancestral to several Eurasian megafaunal species in the Pleistocene. Here we report an early record of a hypercarnivorous canid, *Sinicuon* cf. *Sinicuon dubius*, from Zanda Basin in the Himalaya Range. Although the new record is recovered from reworked sediments in a Pleistocene alluvium, we can constrain the fossil to within a narrow age range of 3.8–3.4 Ma in the middle Pliocene. Presence of this hypercarnivorous canid in the Pliocene of Tibet, along with the recently described pantherine cat and arctic fox, suggests a predator guild with predominately carnivorous diet characteristic of modern arctic carnivorans such as the arctic fox and polar bear. Wintering in extremely cold climates may have been the cause of such adaptations. *Sinicuon* shows transitional morphology to modern hypercarnivorous hunting dogs in southern Asia (*Cuon*), suggesting linkage of the high Tibetan Plateau to the southern continents.

1. Introduction

Based on an ancestral woolly rhinoceros, *Coelodonta thibetana*, we proposed an "out of Tibet" hypothesis postulating that the high Tibetan Plateau was a cradle of evolution for cold-loving Ice Age mammals (Deng et al., 2011). We have subsequently expanded this idea to include the big cats *Panthera blytheae* (Tseng et al., 2013b), the running hyena *Chasmaporthetes gangsriensis* (Tseng et al., 2013a), and the arctic fox *Vulpes* new species (Wang et al., in review). To these, we now add a hypercarnivorous canid, *Sinicuon* cf. *Sinicuon dubius*, from Zanda Basin, southern Tibet (Fig. 1).

The new Tibetan record predates all known occurrences of this taxon in Eurasia, and seems to suggest an "out of Tibet" scenario. Morphologically the various lineages of *Xenocyon* and *Sinicuon* are transitional to the modern hunting dogs, the Asian dhole *Cuon* and the African painted dog *Lycaon*. If *Sinicuon* is indeed ancestral to these living hypercarnivores, then the "out of Tibet" hypothesis can also be expanded to forms in warmer climates in South Asia and Africa.

2. Materials and method

Our usage of Plio-Pleistocene boundary follows the recent decision by the International Commission on Stratigraphy at 2.6 Ma (Gibbard et al., 2010; Pillans and Gibbard, 2012).

Abbreviations: F:AM, Frick Collection, American Museum of Natural History, New York; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

3. Systematic Paleontology

Class Mammalia Linnaeus, 1758
Order Carnivora Bowdich, 1821
Family Canidae Fischer von Waldheim, 1817
Subfamily Caninae Fischer von Waldheim, 1817
Tribe Canini Fischer von Waldheim, 1817
Subtribe Canina Fischer von Waldheim, 1817
Sinicuon Kretzoi, 1941

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Sinicuon cf. *S. dubius* (Teilhard de Chardin, 1940)

Xenocyon sp.: Wang et al., 2013a:93
Xenocyon: Wang et al., 2013b:234

Referred specimen. IVPP V18925, left ramal fragment with m1 and m2 alveolus, from IVPP locality ZD1205, 2 km north of the village of Dongsha, N31°19′29.7″ E79°54′30.1″, elevation 4045 m asl, Zanda Basin in Zanda County, Ali District, Tibetan Autonomous Region, China; correlated to 3.81–3.42 Ma (see below) in the Geomagnetic Polarity Time Scale, IVPP locality ZD1205 is close to the boundary between Gaozhuangian-Mazegouan Chinese land mammal stage/age (Qiu et al., 2013); collected by Xiaoming Wang on July 6, 2012.

Stratigraphic and age relationship. Because IVPP V18925 is clearly a reworked specimen secondarily deposited within Quaternary alluvium, it is a matter of some importance to document in detail the stratigraphic relationships. IVPP ZD1205 locality is located in the southeastern Zanda Basin, about 2 km north of the village of Dongsha, and is at the edge of a large alluvium deposit of presumably Quaternary age (younger than 0.5 Ma). The Mio-Pliocene Zanda Formation was cut into a broad valley (Fig. 2), which was filled with Quaternary alluvial gravels and finer sediments from nearby sources. This alluvium was itself being cut by a modern seasonal braided stream, sourced from the Himalaya, which flows northward (Fig. 2). IVPP locality ZD1205 is within a small tongue of the Quaternary alluvium, extending southeastward, that cuts into the Zanda Formation siltstone next to a small exposure of the basement rock (Fig. 3). The basement is composed of serpentines, schist, and quartz veins.

Within this small tongue, interbedded gravels and siltstones form the top 5 m of the Quaternary alluvium, which is underlain by a sequence of dark gray coarse gravels of approximately 20–30 m thick (Fig. 3A). IVPP locality ZD1205 is within the upper buff interbedded silt and gravel layer, about 2 m above the dark gray gravel unit (Fig. 3A and B). Gravels consist of mostly dark clasts of basement rocks that are poorly sorted, poorly rounded, and matrix supported. The light buff colored matrix is largely consisted of eroded silty sediments from the Zanda Formation in the surrounding hills. Both gravels and matrix suggest a nearby source.

Although IVPP ZD1205 locality was clearly within the Quaternary alluvium, we think the canid specimen was reworked from the surrounding hills of Zanda Formation for the following three reasons: 1, the geometry of the alluvial cover is controlled by the local eroded hills of the Zanda Formation sediments (Fig. 2) such that the only possible source of the Quaternary alluvium is nearby hills; 2, both the matrix (eroded Zanda Formation siltstones) and the gravel clasts (eroded basement rocks) suggest local, nearby sources, probably no more than a few meters to a few hundred meters in transport distance; 3, a partial cheek tooth of *Hipparion* (probably *Hipparion zandaense*) (Deng et al., 2012; Wang et al., 2013a), IVPP V18926 (Fig. 4A and B), was also found in the top alluvial beds (within the upper buff interbedded silt and gravel layer); its preservation of strongly permineralized enamel and dentine with dark, rust-iron colored stains is very similar to that on IVPP V18925; the three-toed horse is not known to occur above Pliocene sediments, and relatively abundant hipparionine materials have securely restricted the three-toed horse to 5.95–3.36 Ma in Zanda Basin (Wang et al., 2013a). It is thus likely that all non-basement component (everything excluding dark, metamorphic clasts) of the alluvium are sourced from the Zanda Formation sediments.

Given the above observation, we may further narrow the stratigraphic range where IVPP ZD1205 may have come from. The elevation for locality ZD1205 is 4045 m asl. For the flat-lying Zanda Formation, this means IVPP V18925 could not have been eroded from beds below the level of the Zanda Formation. The upper limit of the local Zanda Formation as a source for ZD1205 sediments is more conjectural. Although the local topographic highs (ridges surrounding the local basin) can be as high as 4279 m to the southeast of ZD1205, there is reason to believe that IVPP V18925 was from somewhere much closer, i.e., from an original horizon of much lower relative elevation, because of the pristine condition of the tooth and fragile nature of the lower jaw, which probably did not undergo long distance transport. Assuming a less than 50 m drop in elevation during the erosion and transport process, i.e., less than 300 m of horizontal transport from nearest hills with elevation of about 4100 m, IVPP V18925 was thus estimated to come from the 4045–4095 m level of the local Zanda Formation. The assumption of less than 50 m vertical drop in surface transport before re-burial of the specimen is justified given our frequent field observations that most fossils from the Zanda Formation are destroyed within a few meters of their original points of erosion, and that the poorly preserved *Hipparion* cheek tooth (IVPP V18926; Fig. 4A and B) from IVPP ZD1206 locality was horizontally transported by at least 200 m from the nearest edge of the Quaternary alluvium. Using the same correlation scheme as in Wang et al. (2013a), the above estimates translate to approximately the 469–525 m level of the South Zanda section by Saylor et al. (2010) that correspond to the middle part of C2Ar to the middle of C2An.3n of the Geomagnetic Polarity Time Scale (GPTS) with an estimated age of 3.8–3.4 Ma in the ATNTS2012 scale in Hilgen et al. (2012), middle Pliocene. The fact that the youngest in situ *Hipparion* in Zanda Formation is 3.36 Ma (Wang et al., 2013a) is also consistent with the above age estimates.

Description (Fig. 4C–E; Table 1). Represented by a single jaw fragment, this specimen is nonetheless highly distinct in its very hypercarnivorous lower first molar. The horizontal ramus does not preserve the ventral border, and the jaw depth cannot be observed. The perfectly preserved m1 is the most diagnostic tooth for this canid. The hypercarnivorous characters are shown in its elongated, narrow, sharply bladed trigonid that are mainly formed by a tall-crowned paraconid-protoconid blade. The metaconid is much reduced, with its apex barely above the hypoconid. There is a distinct ridge at the posteromedial aspect of the trigonid leading down from the tip of the protoconid to the metaconid. The talonid is narrow and tapers posteriorly. The hypoconid is almost centrally located as the only cusp in the talonid, flanked medially by a low and narrow cingulum that runs along much of the length of the talonid. A conical entoconid is absent, although it is conceivable that the lingual cingulum may potentially represent a reduced remnant of this cusp.

Table 1
Dental measurements (in mm) of *Sinicuon dubius* and *Xenocyon lycaonoides*. Measurements for m1 length and width of Nihewan specimens are from Hu (2011) and Tong et al. (2012) and the trigonid length is by the authors; those from Yunxian are from Echassoux et al. (2008).

	m1 length	m1 width	m1 Trigonid length
Zanda Basin, Tibet			
IVPP V18925	22.5	8.4	16.1
Huiyu (Zhoukoudian locality 18)			
Uncatalogued	26.5	9.5	
Nihewan (Shanshenmiaozui locality)			
IVPP V17755.05	24.9	10.3	17.1
IVPP V17755.04	25.5	10.4	18.7
IVPP V17755.03	24.8	10.5	18.4
IVPP V17755.21	27.7	10.6	20.0
IVPP V17755.06	25.3	10.1	17.7
IVPP V17755.10	24.7	9.6	17.0
Yunxian			
Yunxian 743-326	22.5	9.3	
Yunxian 743-274	25.2	9.8	
Yunxian 743-265	25.5	9.9	
Yunxian 743-260	24.0	9.2	
Yunxian 743-258	24.0	9.1	